Superconductive Hot-Electron Direct Detectors for Submillimeter Space Telescopes

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We develop a hot-electron direct detector (HEDD) capable of counting single millimeter-wave photons. Such a detector will meet the needs of future space far-infrared missions (NEP ≤ 10^{-19} W/sqrt(Hz) and can be used for background-limited detector arrays on future space telescopes. The HEDD is based on a microbridge (1-μm-size) transition edge sensor fabricated from an ultra-thin film of a superconductor with the critical temperature T_c = 0.1-0.3 K. A very strong temperature dependence of the electron-phonon coupling in superconductors with small electron-mean-free-path allows to adjust the electron-phonon scattering time, tau_{e-ph}, to the desired value. The Nb contacts block the thermal diffusion of hot carriers out of the bridge because of the Andreev reflection. The low electron-phonon heat conductance, high thermal resistance of the contacts, and small heat capacitance of electrons determine the noise equivalent power of ~ 10^{-20} – 10^{-21} W/sqrt(Hz) at T = 0.1 K, which is 100 to 1000 times better than that of the state-of-the-art bolometers. Preliminary results on hafnium and titanium hot-electron bolometers will be reported. The measurements of the electron-phonon relaxation time in hafnium have demonstrated that the bolometer response time of ~ 0.7 ms at T = 0.1 K is possible without using any high-thermal-resistance suspension of the detector (the Hf films were deposited directly on a bulk sapphire substrate). For a device with lateral dimensions 1×1 μm^2, this would result in a NEP ≈ 10^{-20} W/sqrt(Hz) due to the thermal fluctuations. Prototype antenna-coupled devices have been fabricated. These prototypes are being used to test the spectral properties of the detector up to the THz frequencies. Possible ways of integration of these new devices in large monolithic arrays and a multiplexing scheme using a single SQUID amplifier will be discussed.

Topics: D

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